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(Citation)

The Kobe journal of the medical sciences, 25(1):1-17

(Issue Date)

1979-03

(Resource Type)

departmental bulletin paper

(Version)

Version of Record

(URL)

<https://hdl.handle.net/20.500.14094/0100488876>



STUDIES ON THE PECULIARITY OF GRIP STRENGTH
IN RELATION TO BODY POSITIONS AND AGING

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INDEXING WORDS

grip strength; aging; body position; dominant hand; physical fitness

SYNOPSIS

The main purpose of this study was to investigate the peculiarity in isometric strength of both hands in different positions. Subjects were 9,543 healthy males and females from 15 to 55 years of age. Maximum isometric strength was recorded by grip dynamometer (Smedley type). Experiments were conducted with respect to three positions (upright, sitting, and supine). The results obtained were as follows.

Grip strength pyramid by sex and age group showed symmetrically decreased results in the right and left hand in females in comparison with the grip strength of the males of the same age in an upright position ($N = 7.529$). In an upright position, 74.11% of males, and 71.76% of females were observed to get higher value in the right hand. But 7.67% of males, and 10.47% of females put their strength equally on both hands.

Grip strength depended upon body positions in all age groups and in both sexes. Grip strength was stronger in an upright position than in a sitting position. Likewise grip strength was stronger in a sitting position than in a supine position ($N = 2.014$).

The differences in grip strength in relation to three kinds of body positions observed in the experiments were demonstrated by E.M.G. of muscle flexor of digitorum superficialis.

Received for publication November 10, 1978

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INTRODUCTION

Human beings have multiple abilities to take actions under several environmental conditions and to perform many kinds of works with different body positions in accordance with psychosomatic factors. Many muscles cooperate together to perform various kinds of activities. Even in a small movement, several muscles work together with each other. Not only individual muscles but also many of the muscles operate on and off or continuously in our daily life and sports activities owing to the control of nervous system.

Muscle strength is one of the fundamental and component factors for physical fitness, required in daily life and sports activities. Increasing muscle strength contributes significantly to better results of physical performance. Human beings have many kinds of potential abilities to improve and to maintain some level of physical fitness. The improvement of muscle strength is one of the necessary factors in the development of physical fitness for human beings. In addition, reserved strength will be indispensable for various kinds of mental and physical conditions caused by excitements and stressors.

Measurement of muscle strength is considered to be one of the physical fitness tests for average people and also patients in the therapeutic phase and during convalescence. Certain physical conditions can be improved gradually by therapeutic exercises. Grip strength can be considered to be one of the indexes of muscle strength and is generally measured in an upright position. Measurement of grip strength in an upright position, with reference to isometric muscle strength, is one of the physical fitness diagnosis tests fixed by Ministry of Education, Culture and Science in Japan. This test has been done for pupils and students systematically every year since 1964 in Japan.

Many studies have been reported in connection with grip strength as measured under several conditions or factors. For instance, Tuttle et al. and Bowie et al. studied on the effect of gripping.^{3,15,21)} Shock and Burke et al. explored the relation of grip strength to aging.^{5,8,18)} Everett et al. and Bower reported in regard to anthropometric measurement of hand and forearm.^{2,10,16,22)} Ishiko and Cotten et al. reported in respect of methods for meas-

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urement.^{6,7,11)} Ono et al. detailed on the grading ability.¹⁷⁾

It must be pointed out, however, that the relation of grip strength to body positions was not evident in these studies. And also mechanism concerning the effect of body positions on grip strength was not found to be documented.

Grip strength would probably be influenced by physical conditions, mental attitude, and environmental conditions. However, it is necessary for us to be able to display grip strength freely and exactly in our daily life or sports activities. Grip strength will be desired to be demonstrated, adapted to purpose of gripping, any time and anywhere by anybody.

Therefore, grip strength in relation to body positions needs to be revealed, and difference in grip strength among the body positions wants to be studied.

In this study, grip strength was experimentally measured with respect to three kinds of body positions.

METHODS AND SUBJECTS

Grip strength of human subjects in three kinds of body positions was recorded. The subjects were asked to grip the dynamometer (Smedley) as hard as possible. Further explanation on the experiments will be presented as follows.

1. Subjects.

9,543 healthy males and females ranging in age from 15 to 55 years served as subjects in this investigation. The number of subjects by sex and age is given in Table 1.

Table 1 The number of subjects by sex and age.

Age	15	16	17	18	19	20	21	22	23	24	25
Male	240	175	113	151	108	210	149	145	158	132	112
Female	248	239	242	285	293	266	187	108	71	77	77
Total	488	414	355	436	401	476	336	253	229	209	189

Age	26	27	28	29	30	31	32	33	34	35	36
Male	133	96	105	96	123	114	123	143	115	124	130
Female	71	68	69	75	100	96	114	111	136	135	158
Total	204	164	174	171	223	210	237	254	251	259	288

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Age	37	38	39	40	41	42	43	44	45	46	47
Male	123	158	119	119	113	125	114	90	105	90	89
Female	134	131	129	123	97	153	113	88	77	81	61
Total	257	289	248	242	210	278	227	178	182	171	150

Age	48	49	50	51	52	53	54	55	Total
Male	75	76	74	61	57	64	55	55	4,757
Female	54	63	58	52	50	32	34	30	4,786
Total	129	139	132	113	107	96	89	85	9,543

2. Measurement of Grip Strength.

Grip strength was measured twice with grip dynamometer (Smedley type) and the higher value was adopted. The width between the two handles of grip dynamometer was adjusted to each subject's hand-size. The width was fixed in the same distance in each position as explained below. Measurement was conducted on each hand in each position at intervals of 5 to 10 minutes.

3. Positions.

Experiments were conducted with respect to three kinds of positions as follows.

- (1) Upright position: The subject stands with his feet shoulder-width apart and his hand relaxed and pendant, and then squeezes.
- (2) Sitting position on the stool: Measurement is done in the same manner as an upright position.
- (3) Supine position: The subject lies on his back on the floor with the dynamometer in his hand, detaches elbow and hand about 3 to 5 centimeters from the floor and squeezes.

4. Dates and Places.

Experiments were held from the 1st of April in 1970 to the 31st of October in 1977 in Hyogo Prefecture at 1) 8 factories, 2) 11 Community Centers, 3) 11 Welfare Offices, 4) Hyogo Prefectural Sports Center, 5) Ashiya Municipal Sports Center, and 6) Mukogawa Women's University.

RESULTS

A. Grip Strength of Right and Left Hand in an Upright Position.

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Grip strength (kg) of both hands for each age group is indicated graphically in Fig. 1.

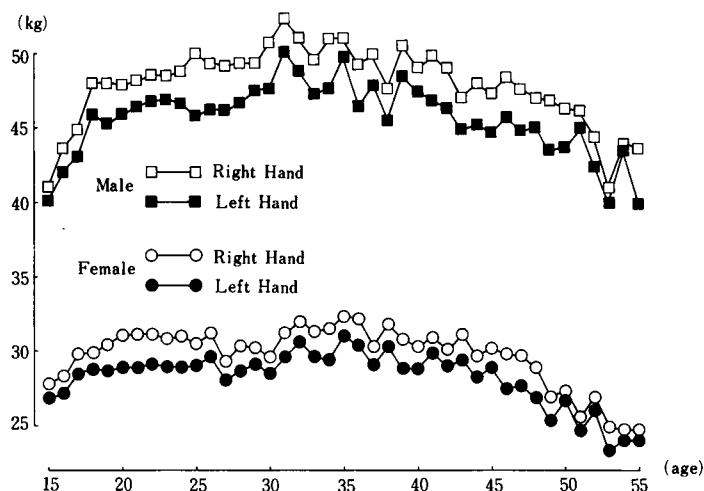


Fig. 1 Comparison of grip strength (kg) between right (R) and left (L) hand in an upright position. (N = 7,529)

Grip strength of males and females showed sex differences and variations between right and left hand. Grip strength of the right hand was to a certain degree stronger than that of the left hand in all age groups.

In males, grip strength of the right and left hand decreased from 52.3 kg for the right hand and 50.1 kg for the left hand at the age of 31 to 40.9 kg for the right hand and 39.9 kg for the left hand at the age of 53. From a view point of age groups, from 15 to 18 years of age, there was a rapid increase in grip strength in both right and left hands in males, which continued up to about 30 years of age. After 30 years of age, grip strength showed a gradual decrease in both the right and left hands up to 55 years of age. Right and left hand grip strength of 53 years of age group was approximately equal to that of 15 years of age group in males.

In females, grip strength of right and left hand decreased from 32.3 kg of right hand and 31.0 kg of left hand at the age of 35 to 24.7 kg of right hand at the age of 55 and 23.3 kg of left hand at the age of 53. From 15 to 20 years of age, grip strength increased gradually in both right and left hands and found a peak

at about 35 years of age. After that, there was a gradual decrease in both the right and left hands in grip strength up to 55 years of age.

Highly significant correlation coefficients were found between grip strength of the right and left hand of all the subjects (0.95 in males, 0.97 in females).

Calculated grip strength (%) of females in comparison with that of males (100%) of the same age is shown graphically in Fig. 2.

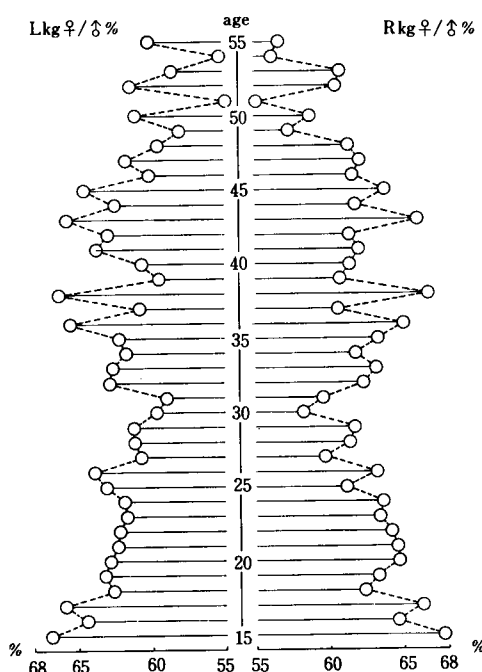


Fig. 2 Grip strength in each hand (%) of females in comparison with that of males (100%) of the same age in an upright position from 15 to 55 years of age. (N = 7.529)

It will be noted in Fig. 2 that grip strength pyramid by sex and age group shows symmetrically decreased results in the right and left hand in females in comparison with the grip strength of the males of the same age in an upright position. In females, grip strength (%) of right and left hand decreased gradually from 67.72% of right hand and 66.89% of left hand at the age of 15 to

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55.21% of right hand and 54.93% of left hand at the age of 51 in an upright position.

In females, the grip strength of both right and left hands (%) gradually decreased from the age of 15 to 30. Then in accordance with age increase until 38 years, grip strength (%) of the right and left hand increased gradually. After 45 years of age, differences between males and females became remarkably greater.

B. Comparison of Grip Strength among the Upright, Sitting and Supine Positions.

Grip strength in relation to three kinds of body positions by sex and by age is shown graphically in Fig. 3.

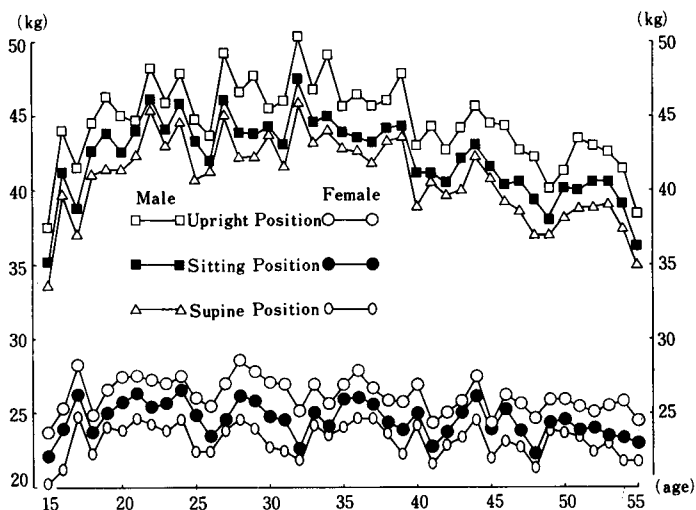


Fig. 3 Grip strength (kg) by age and sex in relation to three kinds of body positions. Record of each hand is added and averaged. (N = 2.014)

In both sexes in all age groups, mean grip strength (kg) in an upright position (44.6 kg in males, 26.1 kg in females) was much stronger than that of the sitting position (42.2 kg in males, 24.5 kg in females). And also mean grip strength in the sitting position was stronger than that of the supine position (40.8 kg in males, 23.2 kg in females).

Calculated grip strength (%) of sitting, and supine position in comparison with that of an upright position (100%) in the same age is presented graphically in Fig. 4.

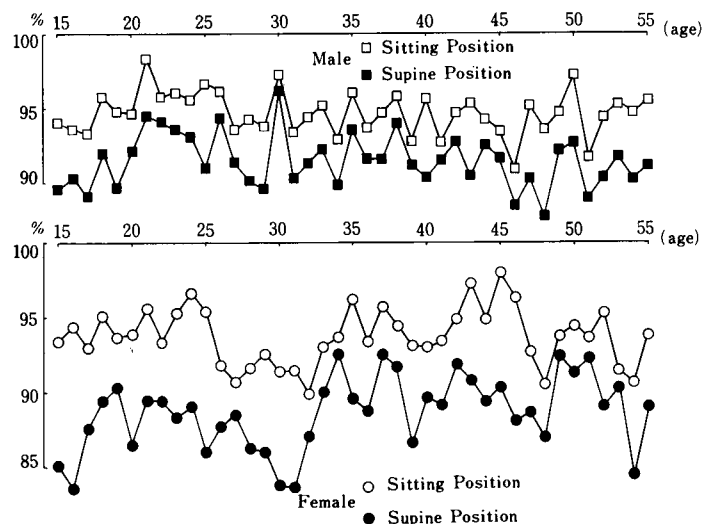


Fig. 4 Grip strength (%) of sitting position and supine position in relation to that of upright position (100%) in the same age group. (N = 2,014)

In males, grip strength (%) in the sitting position ranged from 98.3% at the age of 21 to 90.9% at the age of 46. The mean grip strength score in the sitting position was 94.6% in all age groups in males. And grip strength (%) in the supine position ranged from 97.2% at the age of 21 to 87.7% at the age of 48. The mean grip strength score in supine position was 91.5% in all age groups in males.

In females, grip strength (%) in the sitting position ranged from 98.0% at the age of 45 to 89.9% at the age of 32. Mean grip strength score in the sitting position was 93.8% in all age groups in females. And grip strength (%) in the supine position ranged from 92.5% at the age of 37 to 83.6% at the age of 31. Mean grip strength score in the supine position was 88.7% in all age groups in females.

Comparison of grip strength (kg) between the results of right and left hand in three kinds of positions in relation to age in males is shown by three age trend curve graphically in Fig. 5 and that in females is indicated in Fig. 6.

As is given in these figures of grip strength (kg) of right and left hand, the score was highest in an upright, lower in

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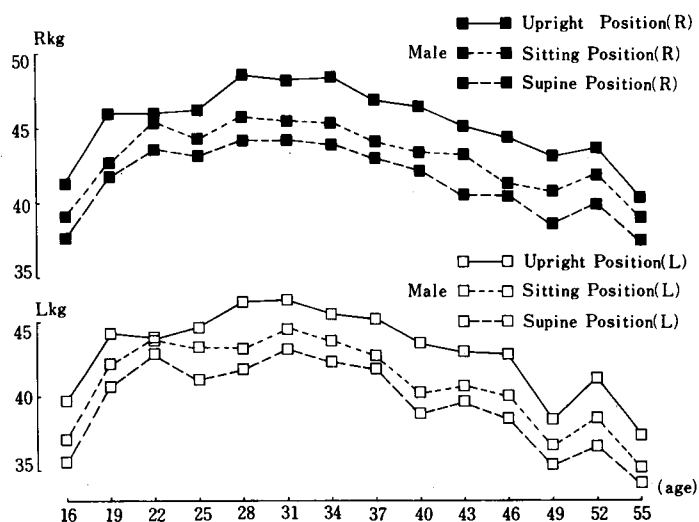


Fig. 5 Comparison of grip strength (right and left) in three kinds of body positions in relation to aging in males by three age trend curve. R: right hand. L: left hand.

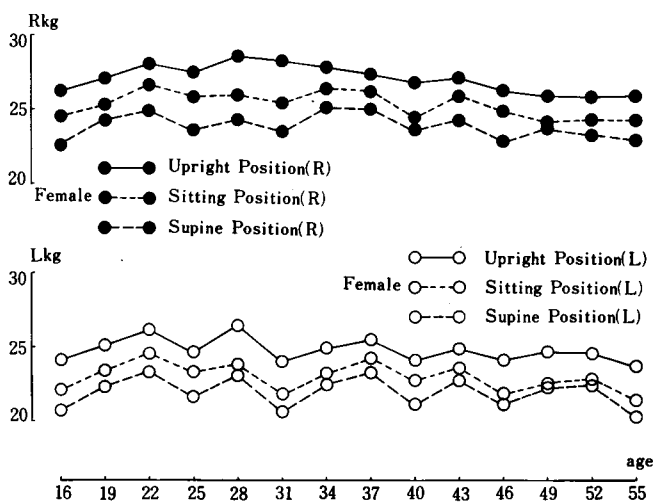


Fig. 6 Comparison of grip strength in the right and left hand by three age trend curve in three kinds of positions in relation to aging in females. R: right hand. L: left hand.

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sitting, and lowest in supine position.

In males in an upright position, mean grip strength (kg) on the right hand in all age groups was 45.5 kg, and range was from 48.6 kg at the age of 28 to 40.3 kg at the age of 55. In the sitting position, mean grip strength (kg) on the right hand in all age groups was 43.1 kg, and lay between 45.8 kg at the age of 28 and 39.0 kg at the age of 55. In the supine position, mean grip strength (kg) on the right hand in all age groups was 41.5 kg, and range was 44.2 kg at the age of 28 through 37.4 kg at the age of 55.

In males in an upright position, mean grip strength (kg) in the left hand in all age groups was 43.2 kg, and range was from 46.5 kg at the age of 31 to 37.4 kg at the age of 55. In the sitting position, mean grip strength (kg) in the left hand in all age groups was 40.9 kg, and lay between 44.5 kg at the age of 31 and 35.2 kg at the age of 55. In the supine position, mean grip strength (kg) in the left hand in all age groups was 39.5 kg, and range was 43.1 kg at the age of 31 through 34.1 kg at the age of 55.

In females in an upright position, mean grip strength (kg) in the right hand in all age groups was 27.0 kg, and range was from 28.5 kg at the age of 28 to 25.8 kg at the age of 52. In the sitting position, mean grip strength (kg) in the right hand in all age groups was 25.4 kg, and lay between 26.6 kg at the age of 22 and 24.2 kg at the age of 55. In the supine position, mean grip strength (kg) in the right hand in all age groups was 23.9 kg and range was 25.1 kg at the age of 34 through 22.6 kg at the age of 15.

In females in an upright position, mean grip strength (kg) in the left hand in all age groups was 24.7 kg, and range was from 26.4 kg at the age of 28 to 23.7 kg at the age of 55. In the sitting position, mean grip strength (kg) in the left hand in all age groups was 23.1 kg, and lay between 24.5 kg at the age of 22 and 21.4 kg at the age of 55. In the supine position, mean grip strength (kg) in the left hand in all age groups was 22.0 kg, and range was 23.3 kg at the age of 37 through 20.3 kg at the age of 55.

As shown graphically by three age trend curve in Figs. 5 & 6, highly significant correlation coefficients were found in all age

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groups between upright position and sitting position (0.95 on the right hand, 0.96 on the left hand in males; 0.85 in the right hand, 0.89 in the left hand in females) and between sitting position and supine position (0.98 in the right hand, 0.98 in the left hand in males; 0.83 in the right hand, 0.91 in the left hand in females).

In accordance with muscle contraction, decreasing recruitments and frequency coding were found in E.M.G., which is shown in Fig. 7. (E.M.G. were led-off by bipolar surface electrode.)

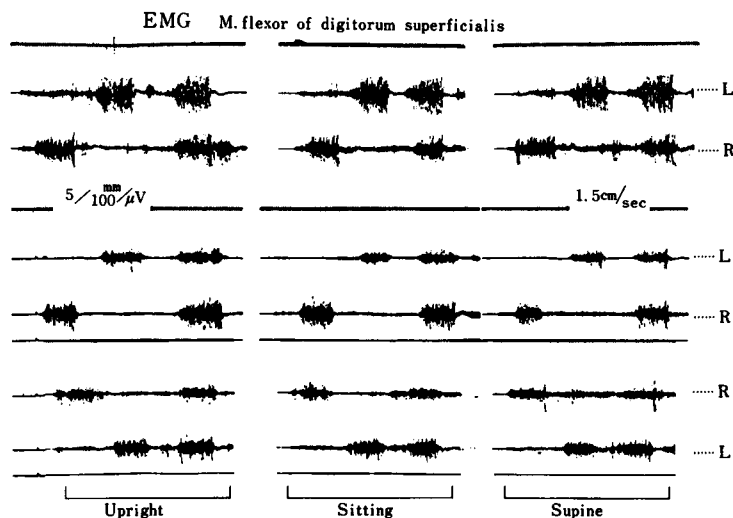


Fig. 7 E.M.G. of muscle flexor of digitorum superficialis in relation to three kinds of body positions. (upright, sitting, and supine position) R: right hand. L: left hand.

As indicated in discharging pattern, some differences were found among the three kinds of body positions and between the right and left hand, when the subjects squeezed not only in one side (gripping hand) but also simultaneously in both sides (right and left hand).

Mutual correlation between measured mean grip strength (kg) in three different positions in all age groups in males and females was calculated.

Highly significant correlation coefficients were found in both sexes, between upright position and sitting position (0.92 in

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males, 0.82 in females), between sitting position and supine position (0.97 in males, 0.86 in females) and between upright position and supine position (0.89 in males, 0.69 in females).

DISCUSSION

In this study, the measurement of grip strength in relation to three positions was executed on subjects ranging from 15 to 55 years of age. The analysis of variance outcome indicated that grip strength of both hands was varied with both sexes of all the age groups, and with the three positions, which may be due to functional differences, physical fitness, and so on.

There have been several reports on grip strength as follows. Ishiko¹¹⁾ studied on the relationship between the grip strengths measured with fixed grip dynamometer with the hand first shoulder high and next pendant in an upright position among males and females aged 5 to 20.

The muscle group, with regard to grip strength, did not show any different mechanism when the grip strength was measured with fixed dynamometer with the hand either shoulder high or pendant.

Shock¹⁸⁾ indicated that although the dominant hand was stronger at all ages, it lost more of its strength over the years than the subordinate hand.

De Vries⁸⁾ elucidated that strength decreased very slowly during maturity. After the fifth decade, strength decreased at a greater rate, with women's losses being somewhat greater than those of men.

In an upright position, the mental and physical strain on the body is greater than that in sitting or supine position. And also the center of body gravity is higher, and supporting base of the body is smaller than the other positions. Physiological condition in an upright position differs from that in the sitting and supine positions.

Beigel¹⁾ demonstrated that body position exerted considerable influence on apperception, thinking, and emotions. The reclining position had a tendency to remove these processes from reality considerations and consequently allowed greater complacency. In the standing position the energies were stimulated toward action and emotions expressed themselves more forcefully. The sitting

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position seemed to favor an equalization between these antagonistic tendencies. It was, however, closer to the standing position than to the reclining position.

In the supine position, only a limited number of muscles can be mobilized. The position depresses some influences on several functions; therefore, supine position allows a decreasing output of energy. It might be considered that gravity affects muscle strength. In the supine position, the level of the center of body gravity is lower and the supporting base of the body is larger than the other positions.

Broer⁴⁾ pointed out that, the larger the base, the more stable the body. Duvall⁹⁾ suggested that the greatest stability was obtained when the base of support was broad, and the center of gravity was low.

It may be considered that there is a close inter-relationship between the environmental influences and the physiological and mental factors in our daily life. Muscle strength depends presumably upon the body position, and the level of the center of the body gravity and the supporting base of the body exert an effect on the physiological conditions under the influences of autonomic and central nervous system and so on.

The tendency seen in this experiment is almost the same as is seen in the experiment of the vital capacity, energy consumption, and pulse rate in three kinds of positions.

According to Karpovich and Sinning¹⁴⁾ an immediate factor that causes adjustment by bodily mechanisms when a change is made from a reclining to a standing position is the effect of gravity on the circulation. Most observations have shown that the pulse rate is definitely affected by body position. The rate is lowest in lying, higher in sitting, and highest in standing. As more muscles are used in standing than in sitting, the demand for energy increases as one moves from the reclining to the sitting, and from the sitting to the standing position.

The study of the action potential of E.M.G. indicated that there was a slight difference in recruitment and frequency coding of impulse in relation to three kinds of body positions.

The author reported¹⁹⁾ that the effect of twice a week physical training for eight weeks upon the grip strength was remarkable. After the training period, grip strength in both hands became

stronger than that before training. The difference in grip strength between the weak and strong side was lessened.

It may be suggested that we should become accustomed to playing or working in some kind of postures under several conditions (for example, in the water, or gravity free conditions in space) as soon as possible to promote ability in sports or work.

It is already reported²⁰⁾ that grip strength of the trained players (Kung Fu, Swimming) decreases slowly when they move from an upright to sitting position and from a sitting to a supine position; however, the untrained men and women show a decrease in a wider range when they move through the same positions.

Because weakness is mainly due to disuse, in order to promote physical fitness, one should make use of the weaker side as frequently as possible in daily life. Almost the equal use of both extremities might be useful to promote physical performance.

It is definitely worthwhile to use both hands, instead of just the dominant one, in daily life.

Ambidextrousness might be useful for sparing energy consumption and continuing physical activities more comfortably for a longer time.

SUMMARY

Grip strength was measured in 4,757 healthy males and 4,786 females, ranging from 15 to 55 years old in three kinds of positions. The results obtained were as follows:

1. Grip strength pyramid by sex and age group showed symmetrically decreasing results in the right and left hand in females in comparison with the males of the same age in an upright position. The ratio of the grip strength of the females to that of the males (100%) was between 67.72% and 55.21% in the right hand, and 66.89% and 54.93% in the left hand. (N = 7.529)
2. Highly significant correlation coefficients were found between grip strength of right and left hand of all the subjects (0.95 in males, 0.97 in females).
3. Grip strength was stronger in an upright position (100%) than in the sitting position (94.58% in males, 93.77% in females)

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in all age groups. (N = 2.014)

The difference of two positions was statistically significant. ($p < 0.001$)

4. Grip strength was stronger in the sitting position (100%) than in supine position (96.66% in males, 94.53% in females) in all age groups.

The difference of two positions was statistically significant. ($p < 0.001$)

5. It was clearly indicated that grip strength was stronger in an upright position (100%) than in the supine position (91.47% in males, 88.65% in females) in all age groups.

The difference of two positions was statistically significant. ($p < 0.001$)

6. These phenomena of decreasing grip strength (3, 4, 5 above) were found in both sexes and age groups.

7. In accordance with the change of body position, decreasing grip strength was estimated from E.M.G. of muscle flexor of digitorum superficialis, not only in one side (gripping hand) but also simultaneously in both hands.

ACKNOWLEDGEMENTS

The author wishes to express his sincere appreciation to Prof. Yoshiaki Toda (Dept. of Hygiene, Kobe University School of Medicine) for his continuous suggestions and advice.

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